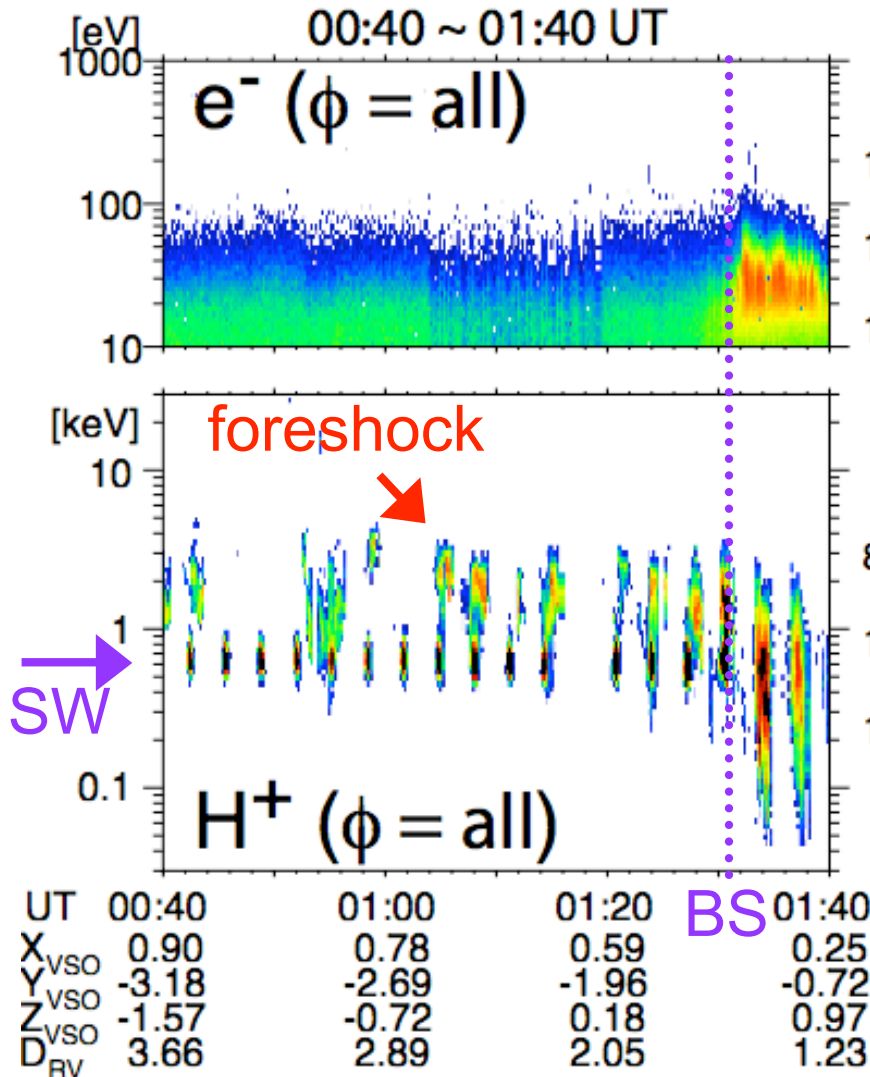# Oxygen Foreshock of Mars

M. Yamauchi[1]; R. Lundin[1]; R.A. Frahm[2]; J.-A. Sauvaud[3], M. Holmstrom[1]; S. Barabash[1]

1. IRF, Kiruna, Sweden
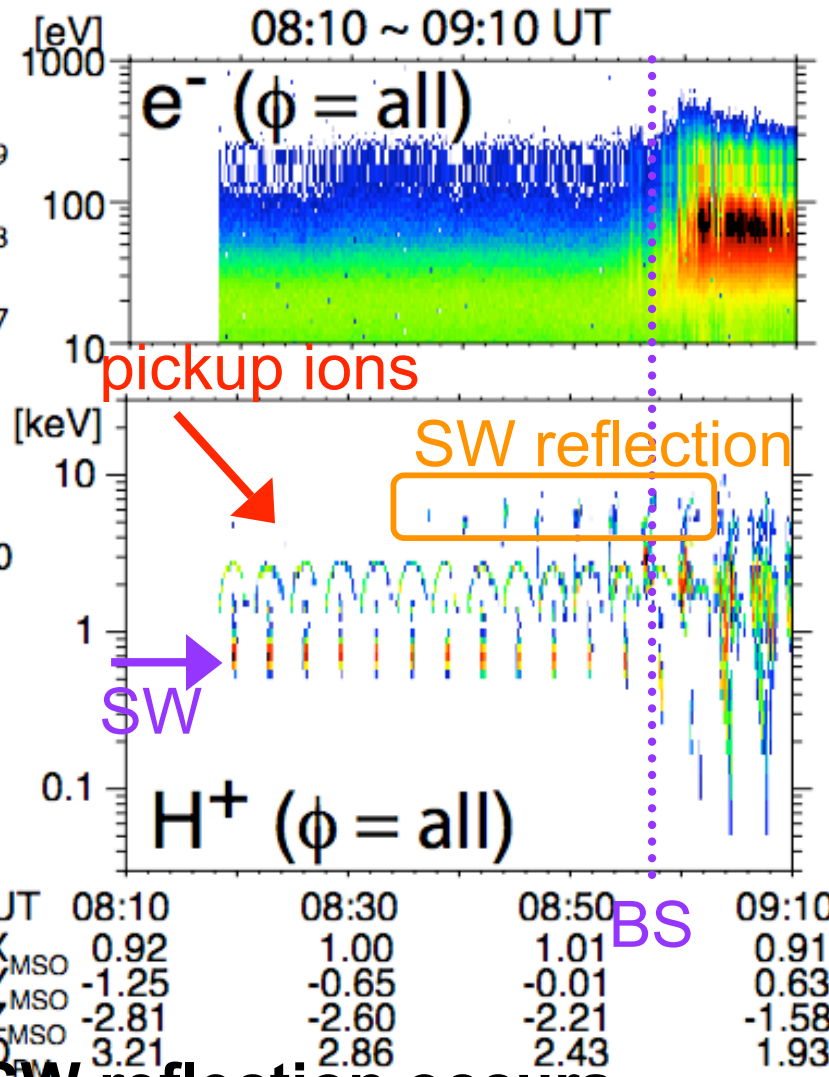2. SwRI, San Antonio, USA
3. IRAP, France

SW observation at Venus/Mars

VEX/ASPERA-4 , 2006-6-19

00:40 ~ 01:40 UT

MEX/ASPERA-3 , 2005-7-12
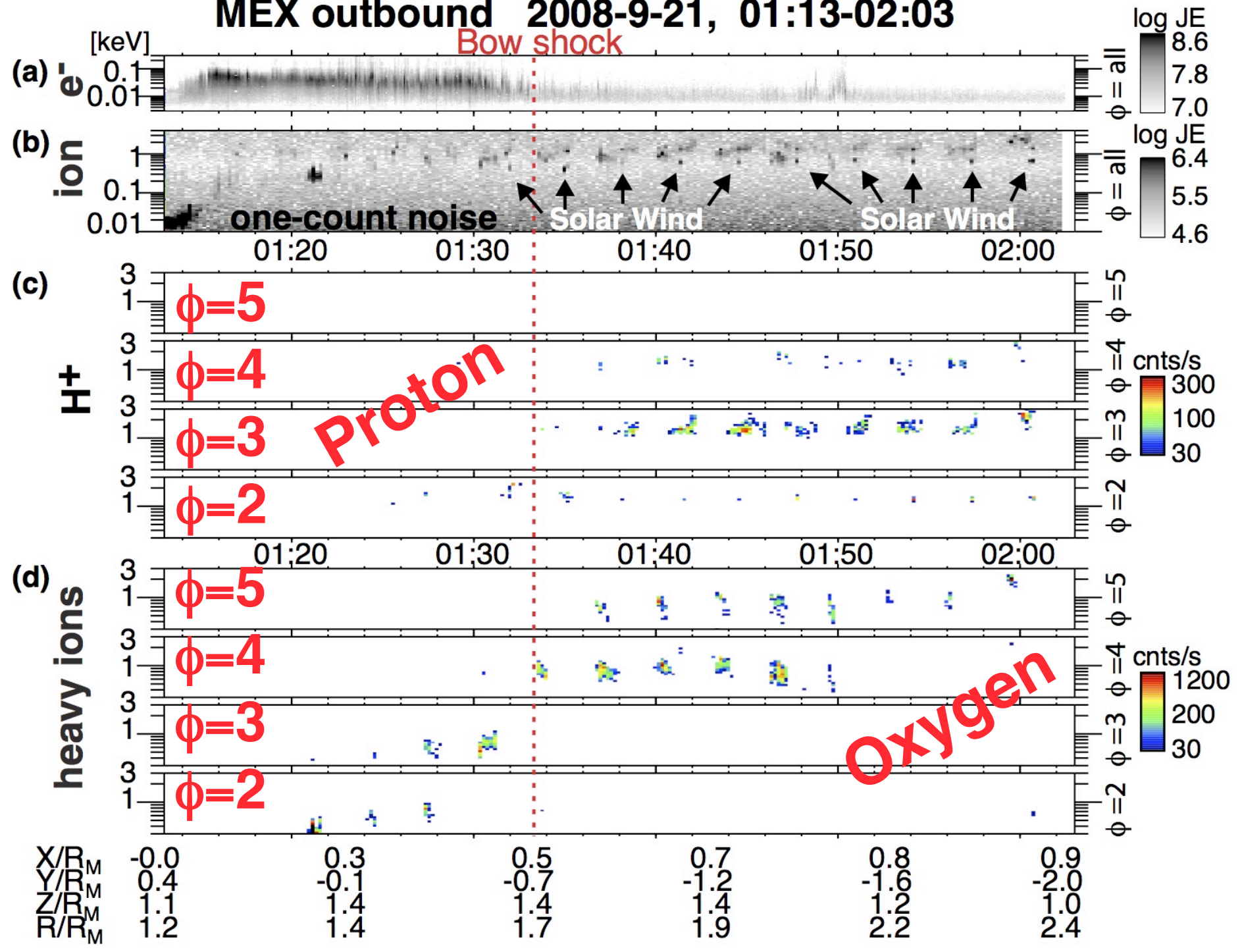
08:10 ~ 09:10 UT

No clear pickup ion

**SW reflection occurs
but no foreshock at X>0**

MEX outbound 2008-9-21, 01:13-02:03
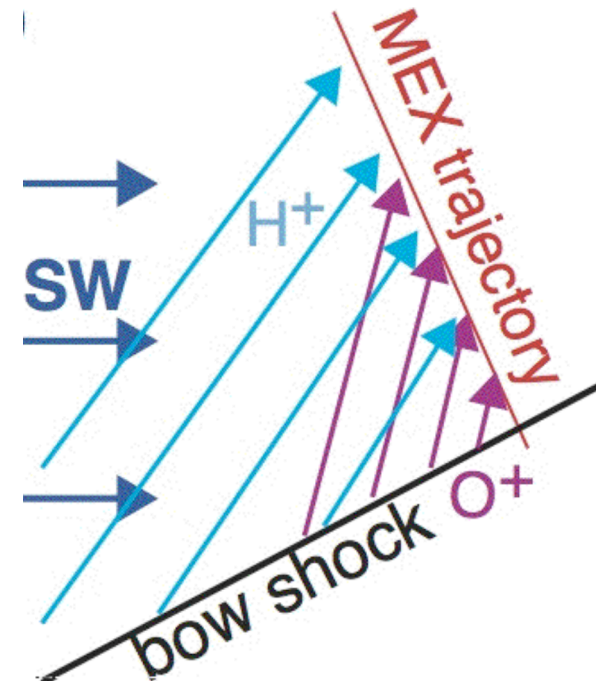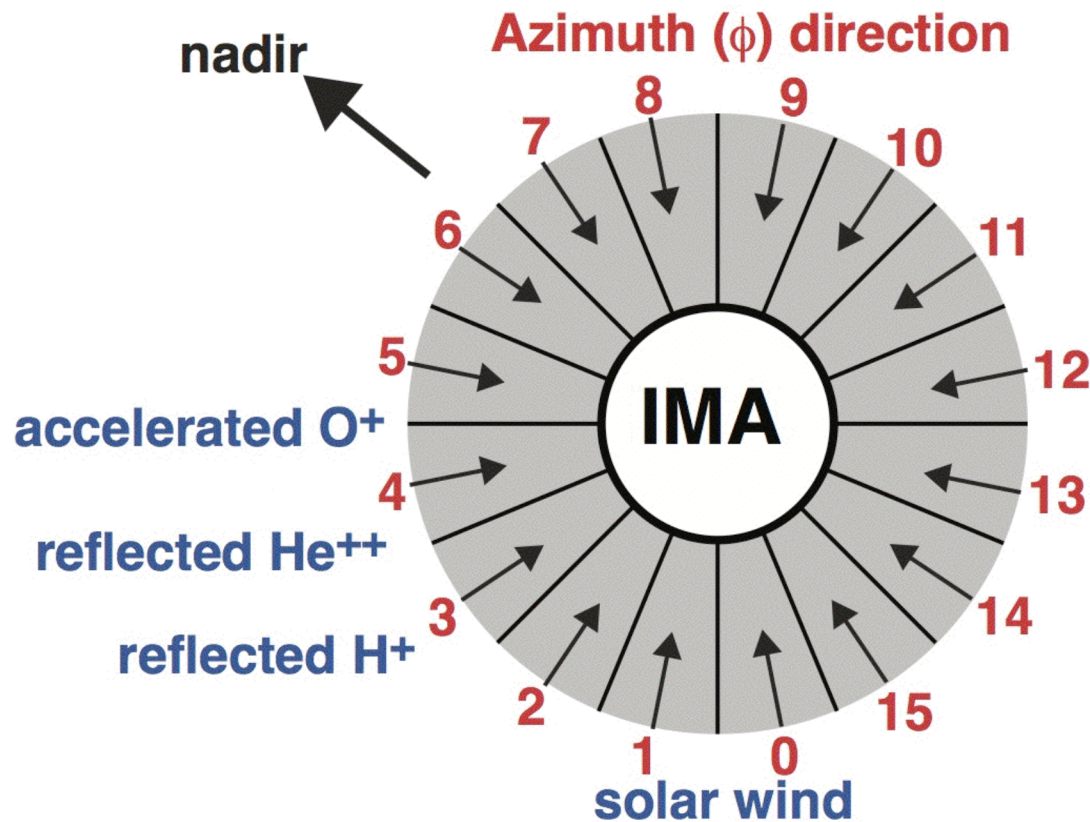
(a) e⁻

(b) ion — one-count noise — Solar Wind — Solar Wind

(c) H⁺ — φ=5, φ=4, φ=3, φ=2 — Proton

(d) heavy ions — φ=5, φ=4, φ=3, φ=2 — Oxygen
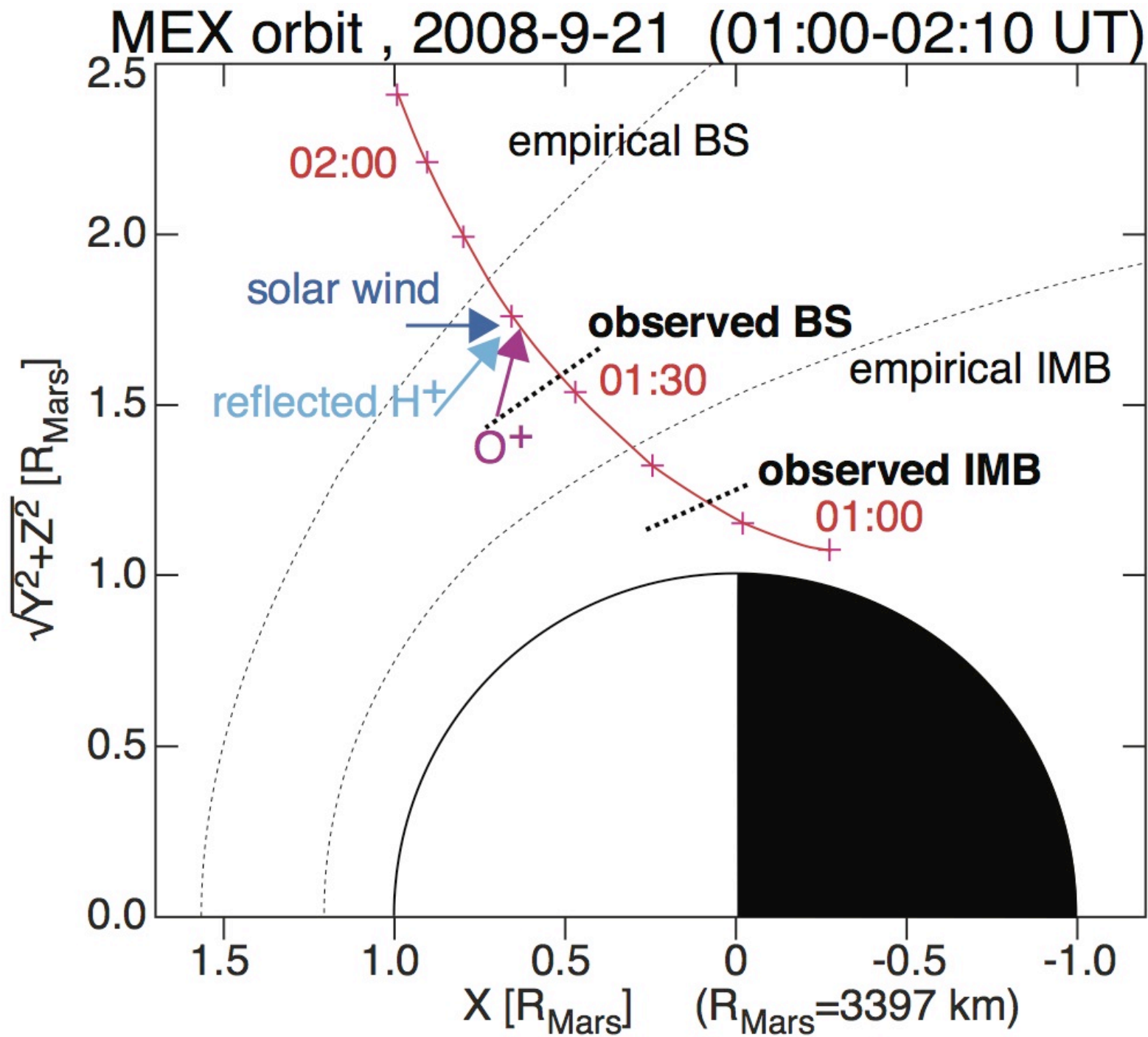
Bow shock

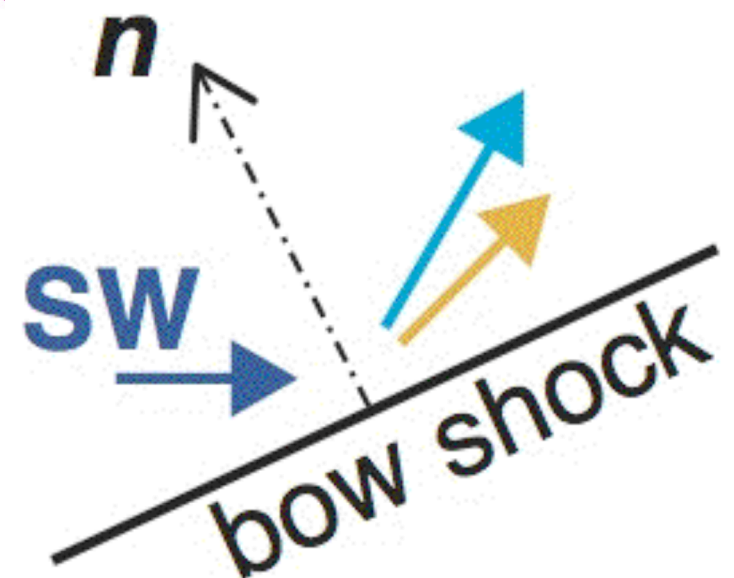# Flow direction (01:40 UT)

(1) O$^+$ foreshock up to > 2000 km from the bow shock.

(2) O$^+$ ≠ H$^+$ for location (by ~1000 km), direction, and energy.

(3) Narrow flow directions (both O$^+$ and H$^+$) ⇒ nearly along B.

(4) O$^+$ acceleration starts from the magnetosheath

Orbit + Flow

MEX orbit , 2008-9-21 (01:00-02:10 UT)

empirical BS

solar wind

reflected H⁺

O⁺

observed BS
01:30

empirical IMB

observed IMB
01:00

02:00

$\sqrt{Y^2+Z^2}$ [R_{Mars}]

X [R_{Mars}]   (R_{Mars}=3397 km)

Further examination

2008-9-21, 01:39-01:42 UT (low mass-resolution mode)

Energy-Mass matrix

$\phi=4, \theta=2-3$ He^{++}? O$^+$ foreshock

$\phi=3, \theta=7-9$ H$^+$ foreshock

$\phi=1, \theta=6-7$ SW m/q=32,16,8 heavy light

cnts/s 200 65 20

$\phi=5, \theta=1-2$ O$^+$ foreshock m/q=32,16,8 heavy light

$\phi=3, \theta=10-11$ H$^+$ foreshock m/q=32,16,8 heavy light

$V_{specular} = V_{in} - 2(V_{in} \cdot n)n$

$V_{observed} = V_{specular} + \Delta V$
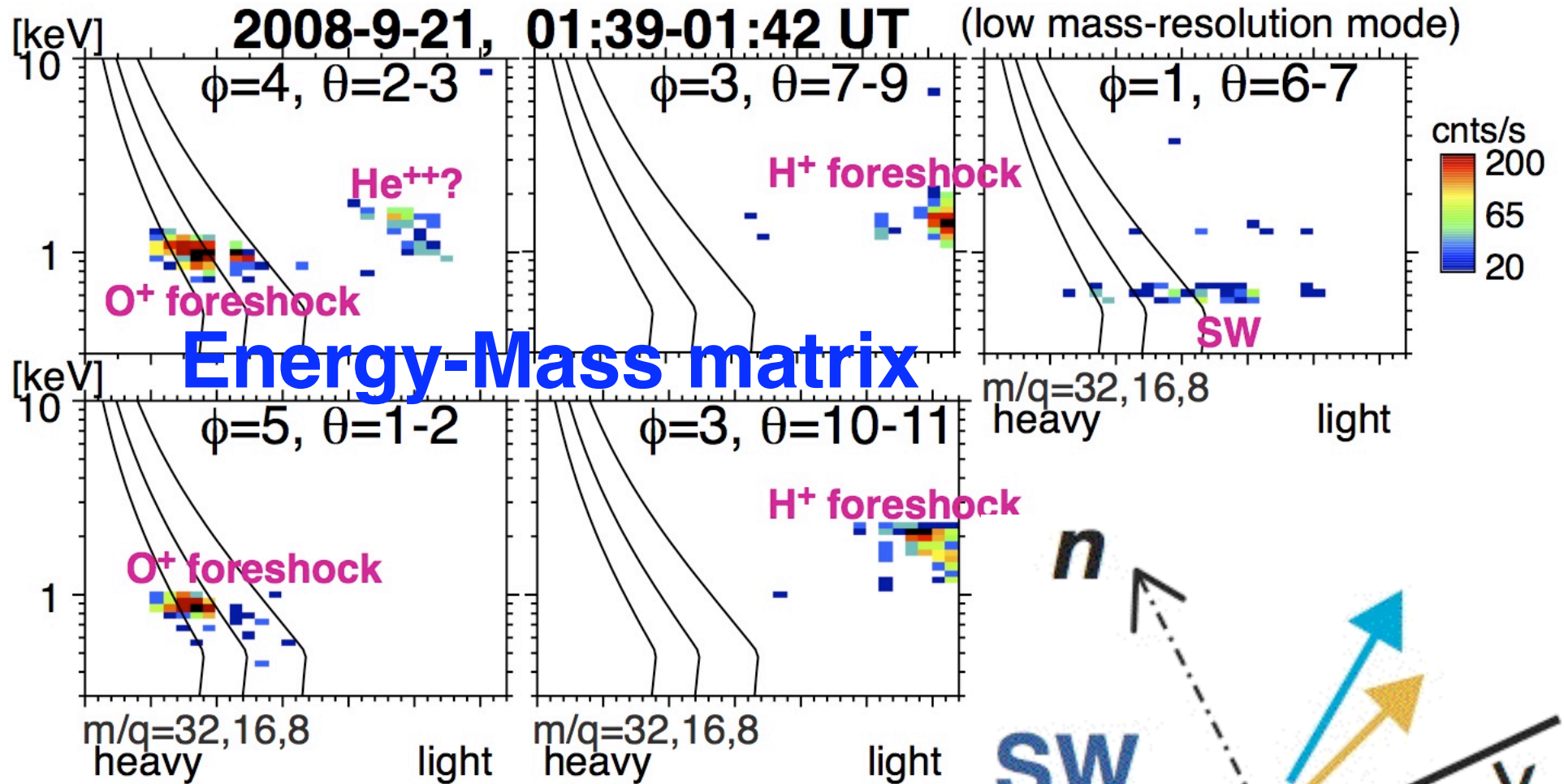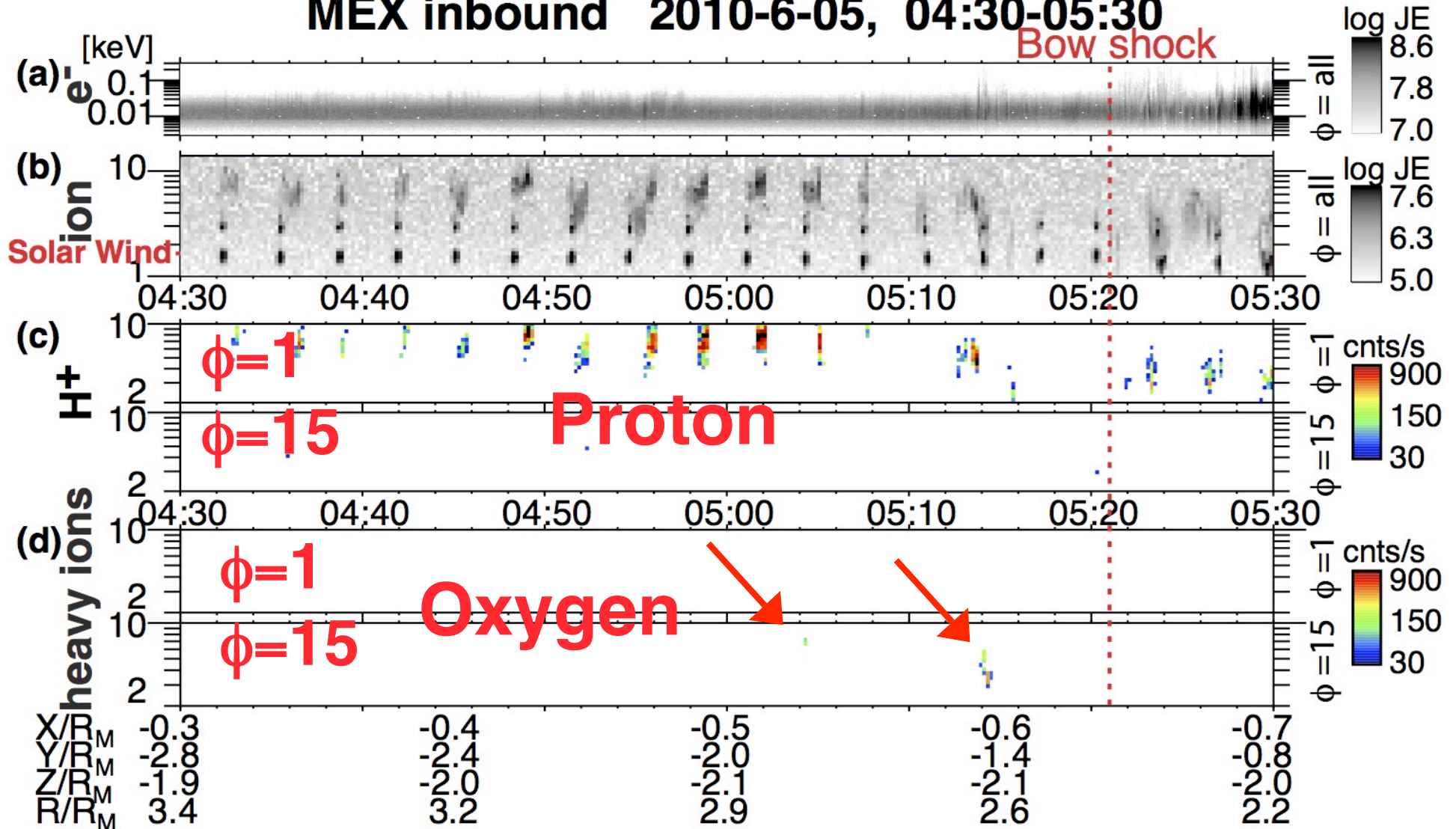
n SW bow shock

Summary of this event

(1) O^+ foreshock up to > 2000 km from the bow shock.

(2) $O^+ \neq H^+$ for location (by ~1000 km), direction, and energy.

(3) Narrow flow directions (both O^+ and H^+) $\Rightarrow$ nearly along B.

(4) O^+ acceleration (nearly // B) starts from the magnetosheath.

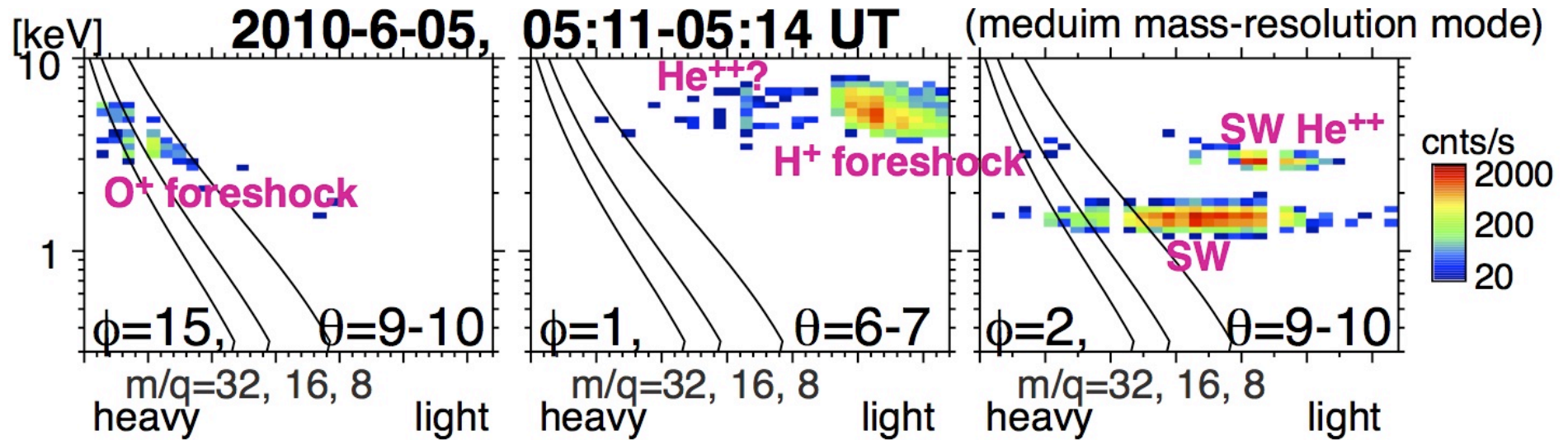(5) foreshock H^+ momentum = specular reflected SW momentum + foreshock O^+ momentum ($\triangle V$).

$\Downarrow$

• O^+ acceleration: most likely electrostatic potential

• H^+ energy gain during reflection: mechanism is unknown.

• Local plasma (in addition to reflected SW) contributes foreshock: raising big question to formation mechanism.
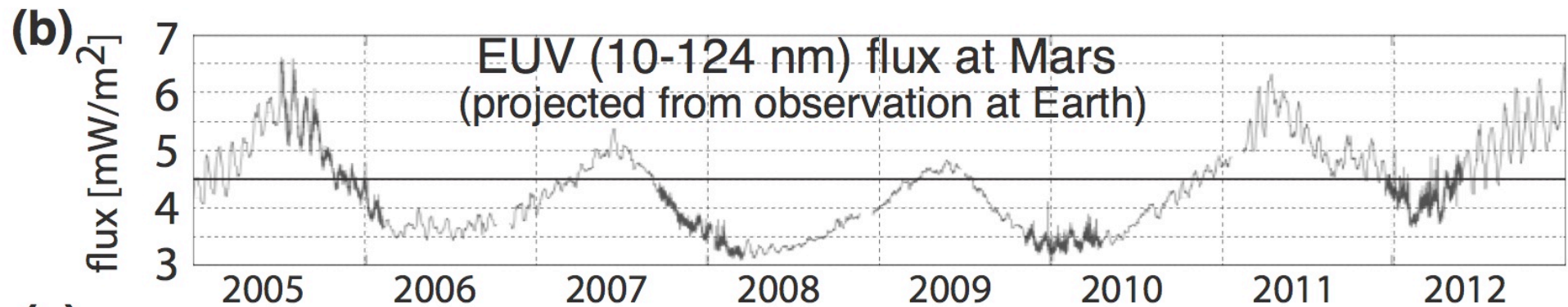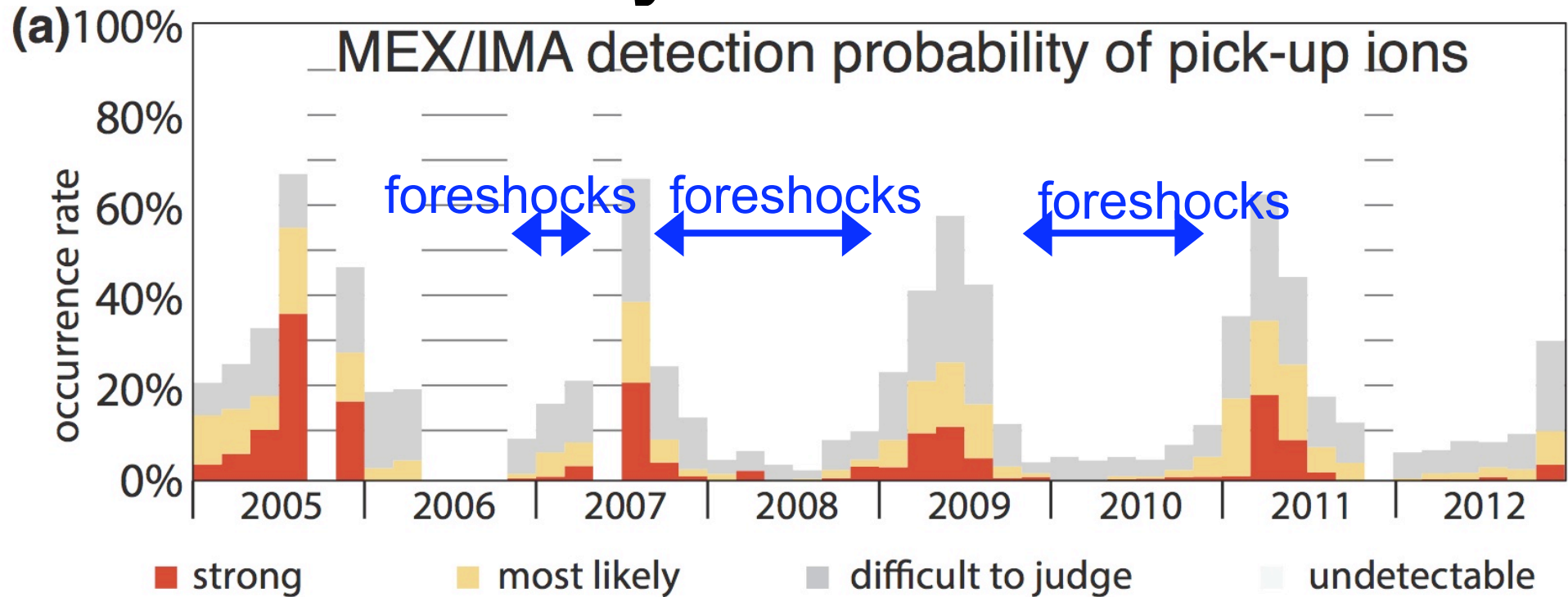
Another example: short-lived

MEX inbound 2010-6-05, 04:30-05:30

Energy-Mass matrix

cf. Survey of H⁺ foreshock

(a) 100% MEX/IMA detection probability of pick-up ions

foreshocks foreshocks foreshocks

Legend: strong | most likely | difficult to judge | undetectable

(b) EUV (10-124 nm) flux at Mars (projected from observation at Earth)

Rough survey over 2005-2010: out of phase between foreshock and pick-up ions

Summary of foreshock survey

(6) Anti-correlated to solar UV or pickup ions.

$\Downarrow$

Background cold ion density might play a role?

$\Downarrow$

Low density favors development of field aligned potential and that favors reflection?

Martian Bow Shock is a best laboratory to study bow shock acceleration

Thank you